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URBAN WASTE AS AN ENERGY SOURCE: A SUSTAINABLE PROPOSAL TO REDUCE GHG AND INEQUALITY IN BRAZIL

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ABSTRACT

The present article has as its object of research the examination of the efficiency of (electric) energy generation through the application of urban waste in Brazilian society. The objective of the investigation is to certify that the application of public and private policies for the correct disposal of waste will bring as an explicit repercussion clean energy sources and, as a result, will cooperate to reduce GHGs and mitigate social contrasts, especially in Brazil. The research aims to answer the following problem: "How to dispose of solid waste without damaging the environment and build sustainable development and citizenship?". We work with theoretical-empirical research under the deductive method. The bibliographic survey is based on authors with emphasis on the modeling of the State with public policy solution, as well as interviews, in order to establish a reflective dialogue between the theory and the object of investigation. The research analyzes scientific studies and graphs that correlate poverty in the Brazilian state with lack of access to energy and the pollution caused due to irregular garbage disposal. As a result, a position presented as a solution to the problem of basic sanitation in the neediest regions is achieved.

Keywords: Solid waste. Incinerator. Waster-to-energy. Energy recovery.

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INTRODUCTION

The global discussions on the energy transition, through the search for and confirmation of clean and sustainable energy sources, do not only echo in the scenario of energy security and mitigation of the handling of energy sources that cause Greenhouse Gases (GHG) harmful to the environment, but, as an initial and elementary rule, in the connection with citizenship and public policy. Nevertheless, climate change directly affects the communities most in need of minimum conditions for a healthy life.

The concern about solid waste arose at the International Congress on Natural Disasters of the United Nations (UN), in 2015, in Sendai, Japan, where the researcher presented the game "Civil Defense: Adventure" to the Portuguese-speaking community. Later, he walked around the Japanese city and bought a soft drink at *hanbaiki* or *vending maines*. He entered a *fast-food restaurant* and asked the attendant to dispose of the can in the trash can. However, he had the answer "*the trash is yours*[23]".

The object of this article is to study the valence of energy generation through the application of urban waste in Brazilian cities. It is undeniable that environmental issues attract increasing attention today, and the centrality of the principles of environmental justice to ecological protection, economic activity, or even the future of Brazilian democracy still needs to be recognized.

It is in the cities that most of the anthropocene population lives, because there is even more affluence in these places, so that the climate policies shaped need to see, especially the miserable. It is observed that citizenship expresses a set of rights that gives the person the possibility of actively participating in the life and government of his country.

The justification for this investigation arises from the concern with the impacts caused by the high demand for industrialized products, which results in a large and growing generation of solid waste (recyclable or not), which impacts the adoption of measures for more efficient management. In fact, Brazil has 13 years of National Solid Waste Policy (PNRS), according to Law No. 12,305/2010.

In a world that is approaching 9 billion inhabitants in 2030, including 3 billion new middle-class consumers, the challenge of expanding supply to meet future demand is

[2] *The trash is yours* translation "the trash is yours".
[3] There was, therefore, no other conduct than to take the tinplate to the hotel room and leave it in the bathroom furge. Therefore, there is a need to understand garbage in Brazil both in the Environmental Policing Command of the State of São Paulo, from 2017 to 2019, and in the presidency of the Chico Mendes Institute of Biodiversity (ICMBio), of the Ministry of the Environment (MMA), from 2019 to 2021.

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unprecedented, especially for solid waste generated on the planet, considering the total volumes of landfills and dumps of 5,571, according to the National Information System on Solid Waste Management (SNIR). In addition, methane (GHG) is 20 times more harmful than fossil fuel gas.

In view of the above, it is undeniable that the problem of modern society generates some consequences that must be resolved in order not to enter the tragedy soon. The question is**:** "How to dispose of solid waste without damaging the environment and build sustainable development and citizenship?".

It is worked with the hypothesis that the environmentally appropriate destination will materialize, in the medium and short term, with strong investments in incineration and accelerated composting, because the Waste Derived Fuel (RDF) constitutes the treatment of waste with high calorific value that will be used to feed technology to transform garbage into electricity as a public policy of solid waste in the well-being of the citizenry, Especially, in large urban centers and for the miserable.

In the search for possible answers to the problem raised, the general objective of the investigation was to certify that the application of public and private policies for the correct disposal of waste will bring as an explicit repercussion clean energy sources and, as a result, will cooperate to reduce GHGs and mitigate social contrasts, since, in particular, in Brazil. And as specific objectives: to demonstrate the energy potential of Urban Solid Waste (MSW); to raise the theoretical framework on citizenship, state modeling and sustainable regional development; demonstrate the technological panorama of the energy use of waste; identify which mitigations will be pointed out in the Sustainable Development Goals (SDGs); to point out public policies in solving problems of complexity in the sustainable city; protect the citizen of present and future generations with a healthy environment; and detail basic protocols for the technical intervention teams.

The scientific framework will be worked with theoretical-empirical research under the deductive method, starting from the constitutional text and theories for particular phenomena. It is important to clarify that this type of research involves combining theoretical approaches with empirical data to analyze and confirm previously established hypotheses based on theories. The deductive method, in turn, starts from a general premise to specific conclusions. In this process, the researcher starts with a general theory or law and applies it to particular cases to predict outcomes. The objective is to test the validity of hypotheses, using empirical data to confirm or refute theoretical premises. Thus,

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theoretical-empirical research with a deductive method is a way to test the applicability of theories in practice, using deductive logic to verify whether generalizations are sustained in specific contexts[4].

The research will analyze scientific studies and graphs that correlate poverty in the Brazilian state with lack of access to energy and the pollution caused due to irregular garbage disposal. The investigation will carry out the bibliographic research in national and foreign doctrine, in order to cross the data for interpretation, grounding the research, with contributions from Morin[5], to understand complexity and transdisciplinarity as paths to resolve multipolar conflicts and Mauro Cappelletti, for legal approaches.

PRESENTATION AND ANALYSIS OF DATA

This section presents the results from qualitative and quantitative research. First, the major urban environmental problems that affect needy citizens were raised. Then, the search was carried out on the platform, during 2019 to 2022, in the journal of the Coordination for the Improvement of Higher Education Personnel (CAPES). The model of environmentally appropriate disposal without damaging the environment was created, in order to produce clean energy in the construction of citizenship. After referencing the environmental precepts, the technology used in Brazil was identified. Finally, a semi-structured interview was conducted with agents who applied the public environmental policy in the solution of the tailings.

QUALITATIVE RESEARCH RESULTS

The UN[6] listed the 6 (six) major problems of the Planet, among them: pollution (air, land and soil); heat islands; thermal inversion; acid rain; floods; landslides. This research restricted it to pollution that affects millions of people, that is, soil pollution as a result of garbage dumps, especially dumps, landfills (controlled or sanitary).

[4] SEVERINO, Antonio Joaquim, *Methodology of scientific work,* 24th ed., São Paulo, Cortez, 2018.
[5] MORIN, Edgar, *Complexity and transdisciplinarity*: *the reform of the university and elementary education,* Natal, EDUFRN, 1999.
[6] UN, United Nations, *The UN and the environment,* 16 Sept. 2020, Available at: https://brasil.un.org/pt-br/91223-onu-e-o-meio-ambiente. Accessed in: 10/30/2023.

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HUMAN DEVELOPMENT INDEX (HDI)

The HDI is the quantitative indicator that analyzes the quality of life of a population, including income, education, and longevity variables. The table below presents the HDI values for each Brazilian federative for the year 2021, calculated by the organization Atlas of Human Development of Brazil[7].

Table 1 - HDI values for each Brazilian federation for the year 2021

STATES	HDI
Federal District	0,814
São Paulo	0,806
Santa Catarina	0,792
Minas Gerais	0,774
Rio Grande do Sul	0,771
Holy Spirit	0,771
Paraná	0,769
Rio de Janeiro	0,762
Mato Grosso do Sul	0,742
Goias	0,737
Mato Grosso	0,736
Ceará	0,734
Tocantins	0,731
Rio Grande do Norte	0,728
Pernambuco	0,719
Acre	0,710
Sergipe	0,702
Rondônia	0,700
Amazon	0,700
Roraima	0,699
Paraiba	0,698
Bahia	0,691
Stop	0,690
Piaui	0,690
Amapá	0,688
Alagoas	0,684
Maranhao	0,612

Source: Prepared by the author.

In addition, the 8 (eight) cities with the lowest HDI in Brazil[8] are the following: Melgaço (PA) – HDI – 0.418; Fernando Falcão (MA) – HDI - 0.443; Atalaia do Norte (AM) - HDI – 0.450; Marajá do Sena (MA) – HDI - 0.452 – Uiramutã (RR) – HDI – 0.453; Chaves

[7] BRAZIL, IBGE. Brazilian Institute of Geography and Statistics, *HDI of the states of Brazil 2022,* Available at: https://estados.ibge.gov.br/brasil/panorama. Accessed in: 10/30/2023.
[8] BRAZIL, IBGE, Brazilian Institute of Geography and Statistics, *HDI of the states of Brazil 2022,* Available at: https://estados.ibge.gov.br/brasil/panorama. Accessed in: 10/30/2023.

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(PA) – HDI – 0.453; Jordão (AC) – HDI – 0.469; Bagre (PA) – HDI – 0.471; Piriá Waterfall (PA) – HDI – 0.473; Itamarati (AM) – HDI – 0.477. These cities are all from the Amazon biomes.

The environmentally appropriate destinations of the tailings were surveyed and it was obtained as a result that all cities do not have any type of solid waste treatment, according to SINIR+[9], therefore, in addition to having the lowest HDI in Brazil, they do not have any type of treatment or disposal of solid waste. Thus, we identified this variable of misery with the environmentally appropriate destination of cities.

NATIONAL SOLID WASTE MANAGEMENT INFORMATION SYSTEM (SIN IR+)

Data on the final destination of solid waste from SINIR+ were collected[10] on the website of the Ministry of Environment and Climate Change (MMA), in order to verify the conditions on the environmental impact. The result on the disposal of garbage in Brazil[11] are: 2569 from sanitary landfills; 1509 from controlled landfills and 1493 from dumps, but only 66.6% of the municipalities reporting in the National Sanitation Information System (SNIS), that is, 3,712 managers. In fact, there is no data on any type of solid waste from 1,858 municipalities in Brazil. Thus, the result between undeclared and dump, Brazil has 3,351 cities without treatment.

The results of the research on solid waste were concentrated in the summary of the works, but they had the following data: clear object; goal; methodology; theoretical foundation; result. At this time, a survey of 253 academic works was obtained, 20 of which were master's dissertations and doctoral theses.

[9] SINIR+, National Information System for Solid Waste Management, *Municipal Report on Solid Waste Management,* 2023, Available at: https://sinir.gov.br/relatorios/municipal/. Accessed in: 10/30/2023.
[10] SINIR+, National Solid Waste Management Information System, *National Solid Waste Inventory,* 10 Aug. 2021, Available at: https://sinir.gov.br/relatorios/inventario-nacional/. Accessed in: 10/30/2023.
[11] Waste from domestic activities in urban residences (household waste) and waste from sweeping, cleaning of public places and roads and other urban cleaning services (urban cleaning waste), with only 3,712 declarants in the SNIS of the 5,570 Brazilian municipalities.

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JOURNALS OF THE COORDINATION FOR THE IMPROVEMENT OF HIGHER EDUCATION PERSONNEL (CAPES) ON SOLID WASTE

The bibliographic verification took place in CAPES journals, from 2019 to 2021, of dissertations and theses of the Master's and Doctoral Programs, as well as scientific articles. It resulted in 20 (10 theses and 10 dissertations) and 253 academic articles.

The empirical material collected in the CAPES journal resulted in 190 works on management, 62 management and 01 thesis on "Technical-economic evaluation of an urban solid waste incineration plant in developing countries: a simulation applied to the city of Rio de Janeiro".[12] In the choice of academic works, 3 (three) criteria were chosen: temporal, waste disposal and technological, not obtaining the environmentally appropriate model for the disposal of the tailings.

TECHNOLOGICAL MODELING ON ENVIRONMENTALLY APPROPRIATE DISPOSAL

Technological modeling was carried out to satisfy the following variables: The technological modeling established in the requirements of Federal Law No. 11,445/2007[13], which deals with basic sanitation, Federal Law No. 14,026/2020[14], which updates the legal framework for basic sanitation, and Decree No. 10,936/2022[15], which regulates the PNRS. In addition, establish a model that extinguishes the use of deposits, whether dumps, controlled landfills or sanitary landfills, through the industrialization of the waste treatment process, transforming it into electricity for 600 to 1000 people. In addition, obtain the

[12] ANDRETTI, Fabrício Viana, *Technical-economic evaluation of urban solid waste incineration plant in developing countries - a simulation applied to the city of Rio de Janeiro, Brazil,* 2021, 137 f., Thesis (PhD in Environmental Engineering), Faculty of Engineering, State University of Rio de Janeiro, Rio de Janeiro, 2021.
[13] BRAZIL, *Law No. 11,445, of January 5, 2007,* Establishes the national guidelines for basic sanitation; creates the Interministerial Committee on Basic Sanitation; amends Laws No. 6,766, of December 19, 1979, 8,666, of June 21, 1993, and 8,987, of February 13, 1995; and repeals Law No. 6,528, of May 11, 1978, Available at: https://www.planalto.gov.br/ccivil_03/_ato2007-2010/2007/lei/l11445.htm. Accessed in: 10/30/2023.
[14] BRAZIL, *Law No. 14,026, of July 15, 2020.* Updates the legal framework for basic sanitation and amends Law No. 9,984, of July 17, 2000, to give the National Water and Basic Sanitation Agency (ANA) the competence to issue reference standards on sanitation services, Law No. 10,768, of November 19, 2003, to change the name and attributions of the position of Water Resources Specialist, Law No. 11,107, of April 6, 2005, to prohibit the provision of public services by program contract referred to in article 175 of the Federal Constitution, Law No. 11,445, of January 5, 2007, to improve the structural conditions of basic sanitation in the country, Law No. 12,305, of August 2, 2010, to address the deadlines for the environmentally appropriate final disposal of tailings, Law No. 13,089, of January 12, 2015 (Statute of the Metropolis), to extend its scope of application to micro-regions, and Law No. 13,529, of December 4, 2017, to authorize the Federal Government to participate in a fund with the exclusive purpose of financing specialized technical services, Available at: https://www.planalto.gov.br/ccivil_03/_Ato2019-2022/2020/Lei/L14026.htm#art6. Accessed in: 09/25/2023.
[15] BRAZIL, *Decree No. 10,936, of January 12, 2022*, Regulates Law No. 12,305, of August 2, 2010, which establishes the National Solid Waste Policy, Available at: https://www.in.gov.br/en/web/dou/-/decreto-n-10.936-de-12-de-janeiro-de-2022-373573578 Accessed on: 09/12/2023.

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equivalent carbon credit, which is the representation of methane in the form of CO2, especially without pollution of the air, soil and subsoil, in order to give dignity to the human person and achieve the SDGs, in order to eliminate 5,571 landfills and dumps included in the SNIS in addition to those not declared.

Therefore, the technological modeling for the elimination of tailings was as follows: 1) Reduce tailings from 90% to 100%; 2) Equipment is a Brazilian patent; 3) Imitate gases within Brazilian or world standards; 4)Be modular equipment and compatible with large urban centers; 5) The cost of the equipment is paid in 12 months for cities with 50,000 inhabitants and generate 1,500,000 tons of tailings at a cost of R$ 111.00 to 250 per month; 6) That transforms the tailings into fuel for the production of electricity; 7) That the equipment is innovative for the disposal of tailings; 8) Which is not pyrolysis, gasifier and incinerator; 9) That it is within environmental standards, such as the Brazilian Institute of the Environment and Natural Resources (IBAMA), the National Council for the Environment (CONAMA) and state environmental agencies; 10) Have control of the operation in a safe and simple way. Consequently, the technology for environmentally appropriate disposal should satisfy the above variables, that is, low cost, without polluting the air and soil, producing electricity, reducing waste by 95% to 100% and small dimensions for large urban centers.

DATA ON PYROLYSIS, INCINERATION, GASIFICATION AND OXIDATION-REDUCTION

Thus, through the MMA's transparency portal[16], the following data on pyrolysis, incineration and gasification for the treatment of solid waste were obtained: 1) Solvi: a Brazilian company that operates in the waste management sector and has an incineration and gasification unit in several states of the country; 2) Estre Ambiental: the largest waste management company in the country and in Latin America, and has incineration and gasification in its facilities; 3) CTR-Rio: the Waste Treatment Center is the consortium formed by companies that operates an incineration plant for urban solid waste in the city of Rio de Janeiro; 4) Ecológica Nordeste: a company that operates in waste management and operates with incineration in the Northeast region of Brazil; 5) Waste Reducing Thermo (TR2): uses an oxyreducer and allows the generation of thermal and electrical energy during the process, joining all other existing technologies in the elimination of waste; and 5)

[16] BRAZIL, Ministry of Environment and Climate Change. *Transparency Portal,* 2023, Available at: https://portaldatransparencia.gov.br/orgaos-superiores/44000?ano=2021. Accessed in: 09/23/2023.

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Universities and Research Institutes: some Universities and Institutes have laboratories and pilot units that use pyrolysis, incineration and gasification technologies for studies and development of new waste treatment solutions.

Finally, semi-structured interviews were conducted with public agents at the following levels: National (former Minister of the Environment and former National Secretary of Environmental Quality), State; and Municipal, both in São Paulo. In addition, the company that disposes of solid waste in accordance with technological modeling.

SEMI-STRUCTURED INTERVIEWS WITH PUBLIC AND PRIVATE AGENTS

As previously stated, in order to establish a reflective dialogue between the theory and the object of investigation, semi-structured interviews were conducted with public and private agents, which are contextualized below.

Interviewee 01

As a highlight in the semistructure interview, it was observed the concern of the former Minister of State for the Environment in the environmentally appropriate disposal of solid waste, as he implemented several campaigns and resources to the State and municipalities. In addition, it created the National Zero Landfill Program, which represented the step towards the implementation of the PNRS and gained the awareness of 66.6% of municipal managers to enter their data in SINIR+[17].

Interviewee 02

The former national secretary of environmental quality highlighted the difficulty of environmental awareness at the national level, especially due to the abundance of land in Brazil. The important step was the National Zero Landfill Program, inserting it within the scope of the National Agenda for Urban Environmental Quality to subsidize states and municipalities in the management of MSW with the objective of environmentally appropriate final disposal. He declared that he can carry out a diagnosis of the situation of USW, the desired situation and indicators to evaluate the implementation of the national public policy. In addition, it can create a pragmatic National Action Plan, through the Agenda of Activities, which they update according to the evolution of the program. Thus, in the interactive panel

[17] SINIR+, National Information System for Solid Waste Management. *National Inventory of Solid Waste*, 10 Aug. 2021, Available at: https://sinir.gov.br/relatorios/inventario-nacional/. Accessed in: 10/23/2023.

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it was possible to view maps, graphs and indicators related to the management of MSW and reverse logistics. This technology, through the MMA website, sought solutions to improve environmental quality and contribute to the quality of life in cities. It did not opt for incineration, pyrolysis and gasification because they are environmentally expensive destinations for cities and the State. Thus, the appropriate destinations were controlled or sanitary landfills.

Interviewee 03

The public agent stated that population growth, combined with the increase in industrial activities in the State of São Paulo, has led to a considerable increase in waste production. In addition, the state has an estimated population of 45,919,049; it has 645 municipalities, HDI – 0.78; it has the State Solid Waste Management Plan (PERS); and 556 municipalities included the RS Plan, that is, 86.20% of the State.

The State has 13 consortia in the shared solution: 1) Intermunicipal Consortium of Vale do Paranapanema, with 37 municipalities; 2) Greater ABC Intermunicipal Consortium, with 7 municipalities; 3) Intermunicipal Consortium, with 100 thousand; Environmental Sanitation, with 5 municipalities; 4) Intermunicipal Consortium of Solid Waste of Western São Paulo, with 20 municipalities; 5) Intermunicipal Consortium Vales dos Rios Tiete-Paraná, with 34 municipalities; 6) Intermunicipal Consortium of the Extreme Northwest of São Paulo, with 18 municipalities; 7) Intermunicipal Consortium for the management of solid waste in the Metropolitan Region of Campinas, with 7 municipalities; 8) Intermunicipal Consortium for Sustainable Environmental Development – Cidas, with 12 municipalities; 9) Intermunicipal Consortium of Pontal do Paranapanema – Cipp, with 3 municipalities; 10) Intermunicipal Consortium Tres Rios, with 4 municipalities; 11) Intermunicipal Consortium in the Environmental Sanitation Area – Consab, with 9 municipalities; 12) Consortium of Municipalities of Mogiana – CMM, with 53 municipalities; and 13) Intermunicipal Consortium for Basic Sanitation of the Water Circuit Region, with 13 municipalities. Thus, 77.7% of the municipalities have the Solid Waste Management Plan and allocate 11,960,724 tons to landfills and 1,176,509 tons to dumps or controlled landfills.

Interviewee 04

The municipal assistant secretary of urban cleaning declared that there is a lot of difficulty in the largest city in Latin America. In addition, the population growth combined

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with the increase in industrial activities in the city has also led to a considerable increase in waste production; The city has an estimated population of 12,252,023; it has 32 sub-prefectures, the HDI – 0.805; and has the Municipal Plan for Integrated Solid Waste Management (PMGIRS).

In addition, it has the following landfills: 1) Lumina Inert Landfill, intended for civil construction waste, started in 2011 and does not receive from other municipalities; 2) C.T.R Leste sanitary landfill, intended for solid waste, began in 2011 and does not receive from other municipalities; 3) Riuma sanitary landfill, intended for solid waste, began in 2011 and does not receive from other municipalities; 4) CDR Pedreira Sanitary Landfill – Waste Disposal Center, intended for solid waste, started in 2008 and receives from other municipalities. It does not have incineration in the destination of the MSW.

Interviewee 05

The project was initially born from a pyrolithic chamber in 1999. The big problem at the time was the tires. The objective of the project was to mitigate the problem, such as reducing the environmental impact. So, we looked in Europe for some technology that was viable and would meet the demand for rubber, which was the great environmental problem at the end of the nineteenth century, from 1990 to 2000.

Oxyreduction is the process that brings together incineration, pyrolysis and gasification. The processes are together in the same machine. There are 9 (nine) machines installed in Brazil. In addition, within Law No. 12,305/2010[18] it is cumulated with Normative Instruction 10,936/2022[19]. She indicates two technologies capable of disposing of unusable waste, that is, garbage. It is called waste, because garbage is not considered as something disposable, including what goes to disposal, which is unusable, it is what is used as energy. In addition, the machine is able to obtain the carbon credit.

The carbon credit is entering the national market, so you have to discount this energy that generates thermal energy when it is not used, based on the methane gas that is emitted. In this way, the machine can convert the carbon equivalent, as 14 dollars per ton or 70 euros per ton are obtained to avoid methane gas.

[18] BRAZIL, *Law No. 12,305, of August 2, 2010.* Establishes the National Policy on Solid Waste; amends Law No. 9,605, of February 12, 1998; and provides other provisions, Available at: https://www.planalto.gov.br/ccivil_03/_ato2007-2010/2010/lei/l12305.htm Accessed in: 09/12/2023.
[19] BRAZIL, *Decree No. 10,936, of January 12, 2022.* Regulates Law No. 12,305, of August 2, 2010, which establishes the National Solid Waste Policy, Available at: https://www.in.gov.br/en/web/dou/-/decreto-n-10.936-de-12-de-janeiro-de-2022-373573578 Accessed on: 09/12/2023.

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You have a machine that can linearly generate 100 Kilowatt-hours (kWh). This thermal capacity of one is equivalent to saying one ton of steam per hour. So, when they put them in line, you have the capacity to generate 5 (five) machines aligned, they can generate half a Megawatt-hour (MWh). It is a very reasonable thermal power when talking about extracting this from garbage. When you say you're taking it out of the trash, it's a lot of energy.

The machine has several processes embedded within the overall structure. The first part is telemetry, which is programmed logic control. This is summarized in Programmed Logic Control (PLC); It has the function of managing the entire machine, including weighing all the product that is inserted into the system. So, the first part would be the control of the products that will be eliminated in the process. Then, there is the first Chamber, which is the primary combustion chamber, which is the oxidation-reduction chamber itself. Inside this Chamber there is a cold plasma accelerator that makes the energetic shutdown of every particle that contains energy in it. An example: you take a plastic, throw a plastic there, a contaminated plastic, it will solve all the thermal energy that this plastic can rotate and will leave only the carbon retained in a solid and dry state. So, this plastic, a plastic dirty with meat, for example, with blood, which was made a barbecue, this plastic was stained with blood, it is contaminated with blood as well. So, this plastic will be separated, it will be dissociated and it will turn into gas. So, in the first Chamber, there is oxidation-reduction with a cold plasma accelerator. It turns into any chemical bond into powder, and the result of this chemical dissociation is syngas. So that first camera.

In the second part of the process, the power of this gas is verified, then this gas will generate an energy resultant and the power that is spent generating it in the process is verified. So, you go to the second Chamber, which is the Molecular Dissociation Chamber. All gas forms a molecule, some larger and some smaller, and depending on the type, greater and lesser energy powers.

The administered temperature is the one that manages to zero this environmental impact and this pollution that could eventually happen; So, that's what the machine is for.

The machine is within the law of Solid Waste Policies and the rules of CONAMA and IBAMA. It is modular and has dimensions of 800 square meters. In addition to obtaining cementitious artifices for civil construction with the rest of the tailings; generates hot water; it does reverse logistics; recycling and with five machines in series generates electricity. The value of the machine is two million and eight hundred reais.

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In the following section, the Anthropocene period, the risk society and finally the circular economy will be constructed as opposed to the linear one, in order to reduce the extraction of raw materials and the disposal of tailings.

ANTHROPOCENE, RISK SOCIETY AND THE LINEAR ECONOMY

This section paves the way for the report's foundation of qualitative research data analysis. After being carried out on the CAPES platform, it is noticed that there is no environmental disposal in the national literature

In addition, he pointed out that Brazilian cities with lower HDI indicators do not have an environmentally appropriate disposal of solid waste. Dumps are the destination of solid waste. It is proven, therefore, that public policies in the construction of Brazilian citizenship do not apply existing solutions in technology. Because of the conditions of the cities with the lowest HDI. Brazil has 5,571 (landfills and dumps) that generate methane gases, which are 20 times more harmful than those from fossil fuels and the deforestation of forests or biomes. Thus, we live in the Anthropocene where humans affect the local and territorial ecosystems of life[20].

Villalba[21] explains that the Anthropocene consists of the conceptual line proposed by Earth System Science and accepted by Sustainability Science. Changing this social model requires alignment with everyday life, linear economy, social interests, changes in public policy patterns in conflict resolution, and government competencies.

The Amazon biome represents the largest World Forest with a population of almost 25 million people. However, the lowest Brazilian HDI. Sustainable development must be aligned with the preservation of the environment. In addition, environmentally appropriate disposal must be in the Government's objectives (Federal, State and municipal) to mitigate poverty and generate electricity in the northern region of Brazil.

Linear economics is a model of organization of society based on the increasing extraction of natural resources, in which products made from these resources are used until they are discarded as garbage. Changing this logic of (take-produce-discard) use and discard should be the main objective of countries.

[20] LEFF, Enrique, *Environmental Rationality: the social reappropriation of nature,* Rio de Janeiro, Civilização Brasileira, 2011.
[21] VILLALBA, Bruno, *L'Écologie politique in France,* Paris, La Découverte, 2022.

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Create conditions to generate electricity for the citizen, using the tons of solid waste that cause the environmental impact, especially the miserable populations and with relative public policies. From the production of electricity, from tailings, the SDGs will be achieved, in addition to the goals of the 2030 Agenda.

The SDGs can be mitigated with public policies in the construction of citizenship in the following goals: Drinking water and sanitation (SDG 6); Affordable and Clean Energy (SDG 7); Sustainable city and community (SDG 11); and Action against global climate change (SDG 13). For this reason, researchers, governors (Union, State, Federal District and municipal), parliamentarians and world communities suggest that we are entering the Anthropocene period[22], a new geological era marked by the impact of man and his effects on the Environment[23].

From this behavioral perspective, there will be a change in the social foundation, which starts to give more space to fear and risk. In another turn, it is a society supported by the search for solutions to the risks that are increasingly present. In addition, in the disposal of garbage, in the linear economy and in the preservation of the Environment.

Beck[24] explains about class society as a:

> [...] The utopia of equality contains an abundance of content-positive goals of social change, the utopia of security remains peculiarly negative and defensive: in this case, it is no longer a question of actually achieving something "good", but only of avoiding the worst. The dream of class society is: everyone wants and should share the cake, the goal of the risk society is: everyone should be spared the poison.

The risk society[25], described by Beck[26], would be one in which the citizen is at the limit that no one understands and that produces alternatives for undecided futures. Society is based on the great influence of science and technology and on environmental impact and the end of tradition. It does not mean, in environmental damage[27], a disappeared

[22] The Anthropocene is the proposed name for a new era that dates from the beginning of the Anthropocene .
[23] VILLALBA, Bruno, *L'Écologie politique in France,* Paris, La Découverte, 2022.
[24] BECK, Ulrich, *Sociedade de Risco: rumo a outra modernidade,* São Paulo, editora 34, 2011, p. 59.
[25] "The majority of the Brazilian doctrine states that, only with the adoption of the theory of integral risk, the environment will be effectively protected. In taking care of a diffuse and intergenerational right, its violation would entail an offense to the community and to future generations" (SAMPAIO, José Adércio Leite, Theory of Integral Environmental Risk and Ideology, *Consinter International Journal of Law,* n. I, p. 283-302, 2nd semester of 2015, Available at: https://revistaconsinter.com/index.php/ojs/article/view/387/755 Accessed in: 10/03/2024.
[26] BECK, Ulrich, *Sociedade de Risco: rumo a outra modernidade,* São Paulo, editora 34, 2011.
[27] It is important to clarify that: "Environmental damage has particularities that require a differentiated and more racial treatment: it is dispersed, diffuse, often indeterminate; uncertain others; silent and invisible in many cases, being noticed only after a long time. Damage like this makes it difficult to find the trace of the person who caused it. Such damage deals with the raw material of life, the object of a right that is confused with the condition of possibility of the right itself: an existence so dignified that it is healthy and guaranteed, with the policy of the

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environment, but there are very few aspects of nature that have not suffered human intervention. There is a new kind of concern about what nature can do to us. One begins to be afflicted with the impact of the actions of individuals on the environment. In fact, without meeting the essential needs of existence.

The basic principles of life, of which no one should be deprived: sufficient food, clean water and basic sanitation, access to energy, education and health, decent housing, minimum income and decent work, and access to information and social support networks. The task of the twenty-first century contains this unprecedented challenge, leading all of humanity into that safe and just space.

The Organization for Economic Cooperation and Development (OECD) predicts that the consumer class, with disposable income, will swell from 1.8 billion in 2010 to almost 5 billion in 2030.

With the increase in population and the consequent need to cope with the increase in consumption, forecasts point to quantities above 170 Gt for the next thirty years, which, about the 1970s, will represent an increase 6 six times greater than the amount of resources extracted. However, natural resources, even if renewable, cannot recover at the same speed.

Thus, this report will put a magnifying glass on the final destination of waste to sanitary or incinerated landfills, after the process of selection and treatment in the construction of citizenship as a set of rights in the participation of life and government, bringing considerations about the risk society.

Solid waste has social relevance in all entities of the federation, and especially for citizens in order to have a healthy life. Due to this emphasis on differentiation, the study will have practical implications in the final destination of solid waste. At the same time, the potential of solid waste can be portrayed by identifying the composition, production rate, and theoretical calorific recovery of domestic waste. Therefore, one should aim beyond the PNRS.

right, for the future, future generations" (SAMPAIO, José Adércio Leite, Teoria do Risco Ambiental Integral e Ideología, *Consinter International Journal of Law,* n. I, p. 283-302, 2nd semester of 2015, Available at: https://revistaconsinter.com/index.php/ojs/article/view/387/755 Accessed on: 10/03/2024).

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PUBLIC POLICIES ON SOLID WASTE IN THE CONSTRUCTION OF CITIZENSHIP

The PNRS of Law No. 12,305/10[28] was drafted based on the Federal Constitution of 1988 (CF/88), [29]in its article 24, VI (protection of the environment and pollution control) and VII (liability for damage to the environment and the consumer). It took advantage of the concurrent competence and, being a general rule, it does not exclude the supplementary competence of the States (art. 24, § 2).

Therefore, it must be understood that the law commented on left it to the States, for example, to establish rules on the methodology to be used in the treatment of waste and tailings. As appropriate and if there is "local interest", the Municipalities may intervene by supplementing the federal and state legislation on solid waste (art. 30, I and II, of the CF/88). It is worth emphasizing, therefore, that the Union does not have the competence to legislate privately on solid waste[30].

Among the requirements provided for in the law, we can highlight the extinction of "dumps" in Brazil by 2024[31], the environmentally appropriate final disposal only of waste[32] in landfills, and the prohibition of scavenging, animal husbandry, and installation of housing in landfills.

In addition, the law provided for the expansion of selective collection of recyclable materials to homes, with the priority insertion of cooperatives or associations of waste pickers (Decree No. 11,414/23) and determined that city halls compost organic waste.

The PNRS aims at the shared responsibility[33] for the life cycle of the product between manufacturers, importers, distributors and traders, consumers and holders of public services for urban cleaning and solid waste management, each with their share of participation in the process, from obtaining the raw material to its correct disposal after use.

In this context, reverse logistics, which is an instrument of economic and social development and aims at the collection and restitution of waste

[28] BRAZIL, *Law No. 12,305, of August 2, 2010.* Establishes the National Policy on Solid Waste; amends Law No. 9,605, of February 12, 1998; and provides other provisions, Available at: https://www.planalto.gov.br/ccivil_03/_ato2007-2010/2010/lei/l12305.htm Accessed in: 09/12/2023.
[29] BRAZIL, Constitution (1988), *Constitution of the Federative Republic of Brazil,* Brasília, National Congress, 1988, Available at: http://www.planalto.gov.br/ccivil_03/constituicao/constituicao.htm. Accessed in: 11/06/2023.
[30] RIBEIRO, Daniel V.; MORELLI, Márcio, *Solid waste: Problem or opportunity?,* Rio de Janeiro, Interciência, 2009.
[31] BELLO FILHO, Ney B., On pollution and other environmental crimes, *in* COSTA NETO, Nicolao Dino de Castro e., *Environmental administrative crimes and infractions – Comments on Law 9.605/1998*, Brasília, Brasília Jurídica, 2000.
[32] Tailings are waste that cannot be reused, recycled, etc.
[33] OLIVEIRA, Fabiano Melo Gonçalves de, *Environmental Law,* 3rd ed., Niterói, Impetus, 2013.

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solid to the business sector, so that they can be reused in various ways or return to the production cycle, but only a few products fall under reverse logistics: Pesticide waste and packaging; batteries; Tires; waste and packaging of lubricating oils; fluorescent, sodium vapor, mercury and mixed light lamps; electrical and electronic products and their components; and packaging in general. However, it can be extended to other products and packaging that are not mentioned in the list above when a risk to health or the environment is detected.

Therefore, reserve logistics is a shared responsibility between businesses, consumers, and the government, and everyone has an important role to play in implementing efficient and sustainable systems for collecting, sorting, and disposing of materials and products. The responsibility for the life cycle of products is shared by the consumers.

The PNRS establishes the principles, objectives, instruments, and guidelines, as well as its categories of solid waste classification. The following principles of the PNRS stand out: prevention and precaution; the principle of the polluter and the protector-receiver; sustainable development; eco-efficiency; shared responsibility for the life cycle of products; the recognition that reusable and recyclable solid waste is an economic good and of social value, generator of work and income, and promoter of citizenship and respect for local and regional diversities. The principles contained in the aforementioned article 6 need to be interpreted with permanent integration with the entire body of the law, especially taking into account the definitions (article 3), the objectives (article 7), the general provisions (article 4), the instruments (article 8) and the preliminary provisions of Chapter I of title III.

Nusdeo[34] states that it is important to transfer donors from financing funds to programs for payment of environmental services, to alleviate the problems of undue influence of economic groups in the formulation of this and other environmental policies.

The PNRS has the following objectives: the non-generation, reduction, reuse, recycling and treatment of solid waste, as well as the environmentally appropriate final disposal of waste; the encouragement of the adoption of sustainable patterns of production and consumption of goods and services; the adoption, development and improvement of clean technologies as a way to minimize environmental impacts; the incentive to the

[34] NUSDEO, Ana, *Payment for Environmental Services: Sustainability and Legal Discipline*, São Paulo, Atlas, 2012.

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recycling industry to promote the use of raw materials and inputs derived from recyclable and recycled materials; the integrated management of solid waste; articulation between the different spheres of public power, and between these and the business sector, with a view to continued technical cooperation in the area of solid waste; the regularity, continuity, functionality and universalization of the provision of public services for urban cleaning and solid waste management; the integration of collectors of reusable and recyclable materials in actions that involve shared responsibility for the life cycle of products; the encouragement of the implementation of the product life cycle assessment; the encouragement of environmental labeling and sustainable consumption, but the instruments are the means of management and management in the PNRS.

Among the instruments provided for in Law No. 12,305/2010[35], there are solid waste plans at the National, State, and Micro-regional levels of metropolitan, intermunicipal and municipal regions, which are a condition for the Federal District and municipalities to have access to Union resources that are intended for projects and services related to urban cleaning and solid waste management.

Also instruments of the PNRS are the solid waste management plans; inventories and the Annual Solid Waste Declaration System; selective collection; reverse logistics; sectoral agreements; the terms of commitment; the encouragement of the creation and development of cooperatives or other forms of association of collectors of reusable and recyclable materials; fiscal, financial and credit incentives; and Environmental Information Systems. It is necessary to bring a part of the Aahurs Convention, in force in several countries and which deserves to be imitated: "Information on emissions, which is pertinent to the protection of the environment, must be disclosed".

The 'avenues' of transparency can be summarized as: 1) Uninterrupted collection of information; 2) Complete and truthful organization of existing data; 3) Facilitating access to information; 4) Quick responses to the demands presented; 5) Continuous transmission of information data, in such a way that they reach, without undue intermediaries, their legitimate recipients; 6) Possibility of verifying and discussing the information provided[36].

[35] BRAZIL, *Law No. 12,305, of August 2, 2010*, Establishes the National Solid Waste Policy; amends Law No. 9,605, of February 12, 1998; and provides other provisions, Available at: https://www.planalto.gov.br/ccivil_03/_ato2007-2010/2010/lei/l12305.htm Accessed on: 09/12/2023.
[36] MACHADO, Paulo Affonso Leme, *Right to information and the Environment,* 2nd ed., São Paulo, Malheiros Editores, 2018.

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In addition, the law establishes the classifications: Regarding origin, Waste; households; urban cleaning; urban; commercial establishments and service providers; public basic sanitation services; Industrial; health service; civil construction; agrosilvopastoral; transport services; of mining. Waste from commercial establishments and service providers, if characterized as non-hazardous, may, due to its nature, composition, or volume, be equated to household waste by the municipal government. As for hazardousness, Waste can be hazardous or non-hazardous.

The National Basic Sanitation Policy (PNSB), Federal Law No. 11,445/2007[37], which established the PNSB and established that public basic sanitation services are provided based on several fundamental principles, including universal access, safety, quality, regularity and articulation with health promotion, environmental protection and other policies of relevant social interest, aimed at improving the quality of life, for which basic sanitation is a determining factor.

The policy defines basic sanitation as the set of services, infrastructures, and operational facilities of a) Drinking water supply, b) Sanitary sewage, c) Urban cleaning and solid waste management, and d) Drainage and management of urban rainwater.

It should be noted that the policy specifies that it is necessary to prepare a Basic Sanitation Plan, on which the public basic sanitation service will be based, and, as long as its minimum content provided for in the PNRS is respected, the municipal plan for integrated solid waste management may be included in it. In São Paulo, it established Law No. 12,300/2006[38].

The State Solid Waste Policy (PERS) instituted by Law No. 12,300/06 and regulated by Decree No. 54,645/09[39], which instituted the PERS, before the federal law mentioned above, minimizes the solid waste that public entities and private companies carry out,

[37] BRAZIL, *Law No. 11,445, of January 5, 2007*, Establishes the national guidelines for basic sanitation; creates the Interministerial Committee for Basic Sanitation; amends Laws No. 6,766, of December 19, 1979, 8,666, of June 21, 1993, and 8,987, of February 13, 1995; and repeals Law No. 6,528, of May 11, 1978, Available at: https://www.planalto.gov.br/ccivil_03/_ato2007-2010/2007/lei/l11445.htm. Accessed in: 11/08/2023.
[38] SÃO PAULO, *Law No. 12,300, of March 16, 2006*, Establishes the State Policy on Solid Waste and defines principles and guidelines, Available at: https://www.al.sp.gov.br/repositorio/legislacao/lei/2006/lei-12300-16.03.2006.html Accessed in: 11/08/2023.
[39] SÃO PAULO, *Decree No. 54,645, of August 5, 2009*, Regulates provisions of Law No. 12,300 of 2006, which establishes the State Policy on Solid Waste, and amends item I of article 74 of the Regulation of Law No. 997, of 1976, approved by Decree No. 8,468, of 1976, Available at: https://www.al.sp.gov.br/repositorio/legislacao/decreto/2009/decreto5464505.08.2009.html#:~:text=Regulamenta%20dispositivos%20da%20Lei%20n,n%C2%B0%208.468%2C%20de%201976. Accessed in: 11/08/2023.

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especially in large urban centers, which points out responsibility to all agents involved, for example, producers/importers, consumers and public administration.

The arrangement of the principles of post-consumption responsibility, of the polluter pays and the recognition of reusable and recyclable solid waste as an economic good, generator of work and income, constitutes a step by PERS towards sustainability, in the structuring of product chains. Environmentally appropriate practices of reduction, reuse, recycling, and recovery of energy existing in solid waste should be encouraged with a view to minimizing it.

The main ones brought by PERS are traditional in environmental policy, such as the systemic view in management, which takes into account social, economic, technological, cultural, environmental and public health variables; the principle of pollution prevention through practices that promote the reduction or elimination of waste at the generating source; the promotion of sustainable patterns of production and consumption; the integrated and shared management of solid waste; and the articulation with other policies on the environment, water resources, health, education, sanitation and urban development.

A *WASTE-TO-ENERGY* (WTE)

The management of urban solid waste emerges as a crucial theme for sustainable development in the twenty-first century, seeking effective solutions to the growing challenge of proper waste disposal and treatment. Given the facts mentioned above in this article, it is evident the importance of addressing this problem in a comprehensive and innovative way, considering both the environmental impacts and the need to promote public health, public policies and State modeling, and economic growth.

The generation of electricity from urban waste is an innovative and promising approach to the sustainable management of solid waste in Brazil. This process, known as *waste-to-energy* (WtE), involves converting waste that cannot be recycled, the so-called tailings, into energy, making the most of the potential of these materials and reducing the need for landfills.

WTE, presented as a viable alternative, has been gaining prominence as a solution to face the challenges of waste management in an integrated way. By converting waste into clean energy, WTE not only reduces the amount of waste that is directed to landfills, decreasing the pressure on these sites, but also offers the possibility of generating

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renewable energy. This aspect takes on even greater importance as the world seeks to reduce dependence on fossil fuels and mitigate greenhouse gas emissions.

WTE is not limited to addressing only the energy aspect but also contributes to the minimization of risks to public health since the controlled burning of waste reduces the presence of harmful pathogens and microorganisms. In addition, the reduction of waste volume and the generation of ash as a by-product can be exploited for the production of reusable materials, such as cement artifacts, further closing the material cycle and promoting the circular economy.

The effectiveness of WTE, however, must be considered within a broader solid waste management framework. Priority should still be given to prevention, reduction, reuse, and recycling in line with the established hierarchy. WTE, therefore, emerges as a valuable complement to waste management, especially for waste that cannot be recycled or reused.

By looking at the challenges faced by many countries, such as the presence of inadequate dumps and controlled landfills, WTE takes a strategic role in transforming the way we deal with municipal waste. It not only contributes to the environmentally sound disposal of waste but also offers a sustainable approach to energy production and the promotion of public health.

CONCLUSION

As seen in this article, correctly disposing of solid waste in order to protect the environment and promote sustainable development and citizenship requires the application of appropriate practices that involve society, the government, and the private sector.

Some of the strategies to achieve these goals include: encouraging the production and consumption of products with less environmental impact, such as those with less packaging or long durability; promote public awareness about responsible consumption and the importance of waste reduction; implement effective selective collection systems that involve the population in practices for separating recyclable waste such as paper, plastic, glass and metals; encourage industry to adopt recycling processes, which reduces the need for raw materials and minimizes pressure on natural resources; and encourage the reuse of materials and products for new purposes, preventing them from becoming waste.

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The management of urban solid waste, as discussed, is one of the fundamental pillars for building a more sustainable and healthy future. It involves all steps related to the management of waste generated in cities, from collection to final disposal, including sorting, recycling, and treatment processes. The efficiency of this system is crucial to mitigate environmental impacts, promote public health, and contribute to the circular economy.

Technological innovations are increasingly being incorporated into waste management, with solutions such as waste-to-energy recovery plants, smart monitoring systems for collection and sorting, and more efficient decomposition methods for organic waste.

Finally, efficient management of urban solid waste helps to minimize environmental impacts, reduce pollution, promote the circular economy, and improve the quality of life in cities, which is essential for sustainable development.

In summary, urban solid waste management is a vital element in building a more sustainable and healthy future. WTE emerges as an effective and comprehensive alternative, integrating waste management with clean energy production and the promotion of the circular economy. Successful implementation of WTE requires a collaborative approach between the public sector, the private sector, and society, aiming at optimizing environmental, social, and economic benefits.

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